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Development and Scoring of Hands-On Performance Tests for Mechanical Maintenance Specialties

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1. Enclosure (1) is forwarded as a matter of possible interest.

2. This memorandum reports the procedures used for the development and scoring of hands-on performance tests for the mechanical maintenance phase of the Job Performance Measurement (JPM) Project.

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Development and Scoring of Hands-On Performance Tests for Mechanical Maintenance Specialties

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ABSTRACT

This memorandum reports the procedures used for the development and scoring of hands-on performance tests for the mechanical maintenance phase of the Job Performance Measurement (JPM) Project.

EXECUTIVE SUMMARY

The Job Performance Measurement (JPM) Project is a multiyear effort to validate the Armed Services Vocational Aptitude Battery (ASVAB) against hands-on measures of job performance. The project is testing representative military occupational specialties (MOSs) within each of the four Marine Corps aptitude composites. For the mechanical maintenance composite, automotive mechanics (MOS 3521) and four helicopter specialties (CH-46, MOS 6112; CH-53A/D, MOS 6113; UH/AH, MOS 6114; and CH-53E, MOS 6115) were tested. This research memorandum details the test development process that was used to construct objective, accurate, and representative measures of job performance for each of these MOSs. The test development process had four stages: specification of the job requirements domain, sampling representative content, constructing objective hands-on tests, and establishing standardized scoring procedures.

SPECIFYING JOB REQUIREMENTS

Without a standardized and objective procedure for defining job requirements, JPM hands-on tests could be criticized as not adequately representing what individuals are required to do on the job. The usefulness of JPM results depends on the extent to which the hands-on tests accurately reflect the tasks and behaviors required by mechanics on the job.[1] Therefore, the basis for defining the job requirements for each MOS was the Individual Training Standards (ITSs) for the automotive mechanics and the ITSS MATMEP (Individual Training Standards System: Maintenance Training Management and Evaluation Program) for helicopter mechanics. These documents serve as Marine Corps doctrine on specific job requirements, at the task level, for each of the mechanical MOSs. Extensive job analyses were conducted based on these training materials to organize the job requirements domain and thus facilitate the sampling of test content. Marine Corps subject matter experts (SMEs) extensively reviewed and modified the results of the job analysis. At the end of the analysis, the job domains were organized into matrices that specified the systems (e.g., electrical, hydraulic) and mechanical functions (e.g., troubleshoot, remove, and replace) required of mechanics in conducting their jobs.

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1. CNA Research Contribution 570, *Developing a Competency Scale for Hands-on Measures of Job Proficiency*, by Paul W. Mayberry, Dec 1987.

SAMPLING OF JOB REQUIREMENTS

Each MOS's job requirements included several thousand tasks—far too many to be performed within the eight-hour period allotted for testing. Therefore, Marine Corps SMEs rank-ordered the importance of systems and mechanical functions for each MOS according to how representative and difficult they were.

The representativeness ratings reflected the degree to which performance in one system or function would imply proficient performance in other, lower-ranked, systems or functions. The difficulty ratings were judgments on how difficult it is for an average individual to be trained to perform proficiently on a particular system or function (i.e., time to learn). Rating exercises ranked systems and functions separately on these two dimensions as well as on which system was the most representative/difficult within each function and which function was the most representative/difficult within each system. The outcome of these rating exercises identified "marker" cells within a function-by-system matrix that reflected content areas most representative of performance in the entire domain of job requirements. Difficulty ratings for each cell were also available to assist in sampling of test content.

Despite emphasis on the marker cells the number of tasks within each cell was still considerable. Further analyses were conducted to identify the behaviors associated with performing each task within the cell. These behavioral-element-by-task matrices readily identified the degree of common behaviors across tasks. A sampling plan was devised to select tasks for each MOS so that, in the aggregate, a maximum number of different behaviors were tested. Additional information (such as time to perform, equipment and spare parts needed, and special considerations) was obtained for the sampled tasks to assist in the construction of hands-on tests.

CONSTRUCTING HANDS-ON TESTS

Detailed analyses were conducted for each task selected for hands-on testing. These analyses supplemented the training materials to identify the critical steps required to perform the task. Particular attention was devoted to being able to objectively score the step as successfully performed or not. Ambiguous or non-observable steps were either revised or deleted. Some tasks required modification so that one individual, not a team of mechanics, could perform the tasks. Certain steps of some of the longer tasks were eliminated to reduce testing time. For these tasks, the testing situation was preset to begin at the point where the most critical performance would be scored (e.g., lug nuts and wheel were already off for "remove and replace the brake shoes").

The task analysis attempted to produce initial versions of the hands-on tests that were faithful to the training materials on which they were based and that could be scored objectively. The next step was to conduct tryouts of each hands-on task with job incumbents to be sure that Marine examinees would understand what was expected of them and that test administrators could score each performance step accurately. After performing each task, the job incumbent was debriefed to determine if he understood the instructions and was asked to evaluate the appropriateness of the performance steps on which he was graded relative to how he performed the task on the job. Multiple iterations of this process were conducted with several job incumbents until there was general consensus on the clarity of the test, its fidelity to actual job performance, and the scorability of its steps. In addition, judgments were made concerning how to modify tasks to be appropriate for individual testing, fit within reasonable time limits, and avoid redundant steps.

SCORING OF HANDS-ON TESTS

Hands-on assessment is individualized testing—one examinee performing for one test administrator. The ability of the test administrator to score performance consistently across all mechanics, over time, and for all test content is central to the proper conduct of this testing. Recognizing the pivotal role of the test administrator,[1] the same team of trainers conducted all training, using extensive training materials that were prepared to ensure standardization of training both within and across test sites. Each test administrator completed two weeks of training. The first week was spent learning the specific content of the hands-on tests and how to administer tasks in a standardized manner. Test administrators conducted much role playing as they learned to observe, score, and time hands-on performance. The second week was a complete trial of the full testing evolution using the actual mechanics. Although this was a practice round, test conditions were the same as they would be for the full-scale testing. Test administrator scoring was closely monitored to identify problems immediately and to address questions. At the end of each day of this trial testing, test administrators discussed difficulties that they had and unique circumstances that had not been addressed in the training.

The measurement of mechanical proficiency is complicated by the fact that an experienced mechanic might perform certain aspects of tasks correctly without following the step-by-step procedures of the hands-on test, which were developed from the technical manuals. The mechanic would therefore receive low test scores.

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1. Test administrators were retired and former Marines with relevant mechanical experience and expertise in working closely with young Marines.

An important consideration for this project was the distinction between the process (percentage of steps performed correctly) and the product (whether the final outcome was correct). Additionally, mechanics were timed in the performance of tasks in order to measure their efficiency.

SUMMARY

The procedures used for the development and scoring of the mechanical hands-on performance tests ensured that valid inferences about a Marine's job performance could be drawn from hands-on test scores. ITSs were used as a foundation for defining job requirements; Marine Corps job experts rated each job requirement for how representative it was to the job as a whole. A random sampling procedure selected the tasks to be used from those judged to be most representative.

After tasks were selected, trial testing allowed a preliminary assessment of tasks' feasibility, time limits, and procedures. Retired and former Marine mechanics were hired and trained for two weeks in preparation for serving as test administrators. Continual monitoring during testing minimized the amount of missing data or drift in scoring criteria.

The scoring system ensured that experienced mechanics would not be penalized for using procedures that were more efficient than those specified by the technical manuals. Quality control checks were made, and missing data were imputed where warranted. The consistency of hands-on measurement across testing sites was also examined. No differences between sites were found for the automotive mechanics. Site differences were found for helicopter mechanics that were not reflective of actual differences in proficiency. These differences were adjusted in accordance with suggestions by Marine Corps manpower experts.

The result of these procedures was to ensure that scores from the mechanical maintenance phase of the Job Performance Measurement (JPM) project are highly reflective of performance in the actual job domain.

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INTRODUCTION

The Job Performance Measurement (JPM) Project is a multiyear effort to validate the Armed Services Vocational Aptitude Battery (ASVAB) against hands-on measures of job performance. To validate the ASVAB adequately, test development and scoring must meet high technical standards as well as satisfy the scrutiny of the Marine Corps as being representative measures of job performance. This memorandum details the specification of job requirements, the sampling of elements from job requirements, test development, and the scoring of the hands-on tests, which were administered in the mechanical maintenance phase of the JPM project, in accordance with earlier CNA work [1].

The mechanical maintenance phase of the project presented unique challenges to test development and test scoring. Both automotive and helicopter mechanics are expected to perform an extremely large number of tasks—numbering in the thousands. Since only eight hours of testing was allowed, just a small fraction of the total number of tasks could be tested. Therefore, the procedures for specifying the job domain and for sampling from the job domain were particularly important. Furthermore, because experienced mechanics can often skip steps prescribed in the technical manuals and still successfully perform a particular task, scoring posed a particular challenge for this phase of research. Therefore, "product" scores, which indicated whether the task had been successfully completed, were introduced; in addition, task performance was timed so that each mechanic's efficiency could be measured.

The figure below shows the stages of developing and scoring the mechanical hands-on performance tests, and the products produced at each stage. The first stage is specifying the job requirements domain. Without a standardized and objective procedure for defining job requirements for each MOS, hands-on tests could be criticized as not adequately representing what individuals are required to do on the job. It was determined that the critical components of a mechanic's job could be represented by the systems they work on (e.g., brakes, engines) and the functions they perform (e.g., troubleshoot, remove and replace). Therefore, system-by-function matrices were developed for each MOS.

In stage 2, test content must be randomly sampled from the matrices developed in stage 1. To accomplish this, subject matter experts (SMEs) rated how representative and difficult cells in the system-by-function matrix were. Lists of tasks from the most representative cells were developed, and behavioral similarities across tasks (e.g., selecting proper tools, reading instruments) were listed. Test content was randomly selected to maximize the number of behaviors that were tested within the allotted time.

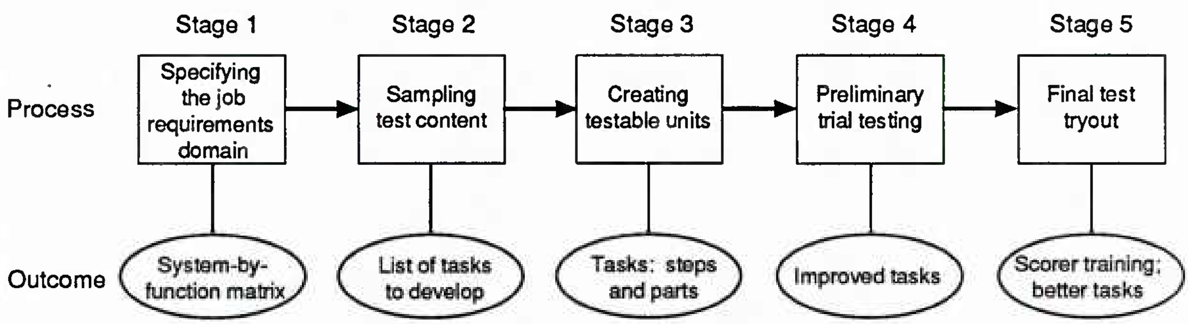

Figure 1. Stages in the development of JPM mechanical maintenance tests

In stage 3, hands-on tests were created from the selected content. To do this, instructions were written that described each task's setup, equipment, safety, and time requirements. Instructions to examinees, score sheets, and instructions for test administration were also developed.

Stage 4, preliminary trial testing, was a "reality check" on the tests created. Members of the test-development staff administered the test to a small number of Marine mechanics. This process allowed determinations to be made concerning the time allowances, parts lists, instructions, and scoring procedures. Revisions were made on the basis of this preliminary test.

After stage 4, tasks were revised and test administrators were trained for a week with the new materials. In stage 5, the newly trained test administrators conducted a "dress rehearsal" of the final testing procedures. This review included all test site setups and a command review by the units providing mechanics for testing. A month-long "stand-down" period was then allowed so that final revisions of test procedures could be completed before the actual testing.

For all of these stages, the general design was similar for the ground and helicopter mechanic MOSs. However, because USMC doctrine differentiates the two sets of MOSs, slightly different approaches were necessary. The Marines specify that an organizational automotive mechanic (MOS 3521) will work on a variety of different types of vehicles. In contrast, each helicopter mechanic MOS corresponds to a specific category of helicopter. Because of this distinction, an effort was made to choose helicopter tasks that were comparable across aircraft systems.

DEVELOPMENT OF THE AUTOMOTIVE MECHANIC TEST

Specifying the Job Requirements Domain

To define the MOS 3521 performance domain, it was essential that a matrix be developed that would define the systems and mechanical functions across vehicles. The Individual Training Standards (ITS) document for MOS 3521, which lists tasks, grouped within duty areas, was used as the initial basis for specifying job requirements. Technical manuals, parts manuals, and programs of instruction (POIs) were also used as supplements for defining the job requirements.

The ITS document lists 15 duty areas, with 2 to 20 tasks in each area. Nevertheless, it proved to be inadequate for a full specification of the MOS 3521 job domain for three reasons [2]. First, the Marine Corps had yet to officially certify the ITSs, although major commands had already reviewed them extensively. Second, the descriptions differed in their levels of specificity; that is, some descriptions were rather simple, others were extremely complex. Last, the ITS document grouped some tasks on the basis of activities; others were grouped by equipment.

To supplement the materials of the ITS document for developing a comprehensive specification of job requirements, Marine Corps subject matter experts, technical manuals, and maintenance allocation charts (MACs) were also consulted. This synthesis of sources resulted in three broad categories useful in evaluating the 3521 job domain: the type of *vehicles* they work on, the *vehicle systems* they work on, and the *functions* that mechanics perform on the vehicles. Table 1 presents a list from these groupings.

Panels of Marine Corps SMEs reviewed the lists of vehicles, systems, and functions. They agreed that the five primary vehicles—M1008, M998, M923, M813, and LVS—were the most important for the job of a 3521, and the most frequently maintained, repaired, and serviced by the typical automotive mechanic. All 3521s have some responsibility for these five vehicles. In contrast, a 3521's experience with additional vehicles (e.g., tactical trailers or refuelers) depends on the mechanic's unit assignment. Therefore, it was decided that testing should focus on the five primary vehicles.

Table 1. Categories for mapping the MOS 3521 job domain

Vehicles	
Primary Vehicles	**Additional Vehicles**
M998, 1-1/4-ton 4 x 4 vehicle	Tactical trailers
M1008, 1-1/4-ton 4 x 4 cargo truck	Trailer refuelers
M813A, 800 series 5-ton cargo truck	Engine cleaners
M923, 900 series 5-ton cargo truck	Lubricating and servicing unit
LVS, Logistical Vehicle System	Wreckers
Systems	
Brake systems	Electrical systems
Drive trains	Diesel engine
Steering systems	Rear-suspension systems
Fuel-delivery systems	Front-suspension systems
Body systems	Chassis systems
Hydraulic systems	Veicle accessories
Recovery/lifting systems	
Functions	
Inspect	Align/adjust
Troubleshoot	Test
Service	Remove/replace

The panels reviewed the original 13 systems and the list of six mechanic functions. They rated the six functions in terms of representativeness and time spent on the function. They then identified omissions and exceptions to tasks noted. For example, 3521s do not repair/replace starters on the M998 vehicle. At the end of this process, the panels agreed that the job performance domain could be accurately described in terms of vehicles, vehicle systems, and mechanic functions. They felt that job requirements concerning administrative functions—dealing with manuals and forms—should also be included in the testing. Finally, they agreed that a system-by-mechanic-function matrix (table 2) could be developed for each of the five vehicles [2].

Sampling Test Content

The 80 cells in table 2 represent the entire 3521 job domain. However, because multiple tasks could be developed within each cell, table 2 still represents much more material than could be tested in an eight-hour period. Because it would be impossible to test the hundreds of tasks represented by the cells, it was imperative to sample from the matrices while maintaining representativeness to the entire job domain.

Table 2. Boundaries of the MOS 3521 job performance domain [2]

Mechanic functions	Systems												
	Brake system	Electric system	Drive train	Diesel engine	Steering system	Rear suspen-sion system	Front suspen-sion system	Body system	Chassis system	Hydraulic system LVS	Vehicle acces-sories	Towing/ lifting acces-sories	Fuel delivery system
Inspect													
Service													
Troubleshoot/ diagnose													
Test													
Adjust/align													
Repair and replace													

NOTE: Each cell in the matrix contains a number of tasks for each of five vehicles: M998, M1008, M813, M923, and LVS.

	Forms	Manuals
Administrative functions		

Super Cells

As a preliminary step of sampling, the panels ranked the 13 systems for representativeness to MOS 3521 with respect to each of the functions and ranked the 6 functions with respect to each of the systems. There was a great deal of agreement that six functions and six systems constituted the crucial and representative core of the MOS 3521 mechanic job. The panel felt that if a mechanic could perform the six functions on the six systems, they could work on any of the systems. The 36 cells in the 6×6 matrix were called "super cells."

Marker Cells

The panels were also asked to respond to the question "If you were to test a 3521 on just *one* of these systems for *this* function, which one would you select?" They were then asked the same information about functions: "If you were able to test on just *one* function for this system, which one would you select?" The cells that SMEs picked most often as the most representative were denoted as "marker cells" [2]. Table 3 shows these cells, summarizing the relationship of the total 3521 job performance domain to the smaller testing domain, and identifies the 12 marker cells with the entire job domain. The testing domain consisted of the 36 super cells, whereas the 12 marker cells represent the portion of the testing domain to be given special emphasis because of the particular importance that SMEs attached to those cells.

Upon further review of the functions, the SME panels determined that the troubleshoot function was partially redundant with certain aspects of the inspect and test functions. Therefore, it was decided for testing purposes to include tasks from the "inspect" and "test" marker cells as part of troubleshooting tasks wherever possible.

Developing Behavioral-Element Matrices

Once the job performance domain was established, it was important to examine systematically the tasks associated with each marker cell. The behaviors required in performing each task were identified, and the comparability of such behaviors across tasks was established. In this manner, the behavioral requirements for mechanical performance were identified, irrespective of tasks. A behavioral-element-by-task matrix was created for each marker cell. Table 4 provides an example for the "test electrical system" cell. The SME panels reviewed and revised these matrices and deleted tasks or behaviors if they (1) could not be tested (e.g., were too long or dangerous); (2) required more than one mechanic to perform; or (3) required equipment that would not be available to a normal motor pool.

Table 3. MOS 3521 job performance domain and testing domain [2]

Mechanic functions	Systems												
	Brake system	Electric system	Drive train	Diesel engine	Steering system	Rear suspension system	Front suspension system	Body system	Chassis system	Hydraulic system LVS	Vehicle accessories	Towing/ lifting accessories	Fuel delivery system
Inspect	●		●										
Service	●			●									
Troubleshoot/ diagnose		●		●						●			
Test		●								●			
Adjust/align					●								
Repair and replace	●		●										

Performance testing domain

● Marker cells

	Forms	Manuals
Administrative functions		

Table 4. Example of task-by-behavioral-element matrix [2]

Behavioral element	Test voltage with multimeter					Test electrolyte specific gravity					Test electrolyte temperature					Test continuity with multimeter				
	998	1008	813	923	LVS	998	1008	813	923	LVS	998	1008	813	923	LVS	998	1008	813	923	LVS
Follow specific safety instructions						•	•	•	•	•	•	•	•	•	•				•	
Set switch to proper position	•	•	•	•	•											•	•	•	•	•
Interpret instrument reading	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Calibrate meter scale (if required by meter)	•	•	•	•	•											•	•	•	•	•
Connect probes across items	•	•	•	•	•											•	•	•	•	•
Observe operation of electrical component																•	•	•	•	•
Install meter probes on meter	•	•	•	•	•											•	•	•	•	•
Install/remove jumper wires	•	•	•	•	•											•	•	•	•	•
Operate vehicle controls and observe results	•	•	•	•	•											•	•	•	•	•
Prepare test equipment	•	•	•	•	•											•	•	•	•	•
Follow general safety precautions	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Select proper tools	•	•	•	•	•						•	•	•	•	•	•	•	•	•	•
Fill out forms	•	•	•	•	•						•	•	•	•	•	•	•	•	•	•
Read manual	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Locate information in manual	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Task Selection

Tasks were weighted by the number of behavioral elements they represented. Based on these weightings, tasks within a marker cell were randomly chosen, so that tasks with a larger number of behavioral elements had a greater probability of selection. When a task was randomly selected, the remaining tasks were re-weighted to exclude previously sampled behavioral elements in an attempt to maximize the number of different behaviors to be tested. Because the matrices were "dense," the behavioral elements were usually exhausted before all tasks in a cell were selected. The subject matter experts reviewed the resulting list of tasks for representativeness and feasibility of testing.

Creating Testable Units

Once tasks had been randomly selected, detailed descriptions of the tasks and the performance steps required to accomplish them were developed. These analyses included the materials required for each task, the sequence of steps, and any special testing or safety conditions. Important considerations at this point were to ensure that appropriate materials needed to perform a task would be available and that tasks could be performed within the time allotted. Therefore, parts lists and tool requirements were an important part of the effort.

Some tasks required modification so that one individual, not a team of mechanics, could perform the tasks. Certain steps of some of the longer tasks were eliminated to reduce testing time. For these tasks, the testing situation was preset to begin at the point where the most critical performance would be scored (e.g., lug nuts and wheel were already off for "remove and replace the brake shoes"). Another consideration was the development of a preliminary scoring format that allowed test administrators to determine whether steps had been performed correctly.

Preliminary Trial Testing

The previous activities defined a set of tasks and testing procedures, but these tests had not been administered to actual Marines. Therefore, preliminary trial tests were conducted to serve as a "shakedown" and as a verification of required equipment, station setup, and scoring procedures.

The preliminary trial testing allowed a number of problems to be identified and corrected, and established the estimated time to complete tasks, parts and tools lists, and manual extracts. It allowed administrators to determine whether all selected tasks could be finished within the specified time limits, or whether further tasks would need to be dropped.

Incomplete or ambiguous instructions were revealed by the questions of the examinees. Deficiencies in station setup and equipment lists became apparent. The trial testing also assisted with the "packaging" of tests into test stations and helped identify ambiguities in the scoring procedures, performance steps that were difficult or impossible to observe, steps that could be effectively combined, and the best positions for administrators to take when scoring.

Final Test Tryouts

Once the procedures and scoring protocols were revised based on the preliminary trial testing, test administrators were trained in the scoring procedures. At the end of the training, final test tryouts were conducted for one week at both west coast and east coast sites to prepare the administrators for the actual testing. These tryouts were a final opportunity to review the clarity of instructions, the assignments of tests to stations, the timing of individual tests, and the feasibility of administering tests within the allotted time. The effectiveness of administrator training could be determined as well.

A command review was performed during the final test tryout, so that commanding officers could see the procedures and make recommendations. After the final tryout, the tests were further revised during a stand-down period of one month before actual testing began.

Content Not Tested

The final test tryouts provided a last opportunity to modify or delete tasks that could not be fitted into the allotted testing time. Overall, few behavioral elements were not tested. Appendix A (Tables A-1 through A-6) shows the behavioral elements tested for each marker cell. As explained earlier, subject matter experts had identified the marker cells as the content most representative of performance in the respective systems and functions. Appendix A shows that essentially all behavioral elements in the marker cells were tested despite testing relatively few tasks. It also shows that when a behavioral element was not tested within one marker cell (e.g., "look for wear" in the inspect brakes cell), it was often covered by a task from another cell (e.g., troubleshooting the electrical system). Arrows in the appendix tables indicate behavioral elements that were not tested by any tasks.

DEVELOPMENT OF HELICOPTER MECHANIC TESTS

The general design for test development and scoring was similar for the ground and helicopter mechanic MOSs. However, because Marine Corps doctrine differentiates the two sets of MOSs, slightly different approaches were necessary. The Marines specify that an organizational automotive mechanic (MOS 3521) will work on a variety of different types of vehicles. In contrast, helicopter mechanics have four different MOSs corresponding to specific categories of helicopter, as follows:

- MOS 6112—CH/46 helicopter
- MOS 6113—CH-53A/D helicopter
- MOS 6114—AH-1J, AH-1T, AH-1W, and UH-1N helicopters
- MOS 6115—CH-53E helicopter.

As a result of these differences, it was important that the hands-on tests for helicopter mechanic include tasks that reflected the unique job requirements across MOSs while trying to maintain comparable test content to assist in later cross-MOS performance comparisons.

Specifying the Job Requirements Domain

The primary source used for specifying the job domain for the four helicopter mechanic MOSs was the ITSS MATMEP (Individual Training Standards System: Maintenance Training Management and Evaluation Program). The ITSS MATMEP is a standardized technical skills training management and evaluation program—it is the program that the Marines use both to specify and to evaluate the technical skills required of helicopter mechanics.

The first activity was to determine which systems were common across the various aircraft. Sorting the MATMEPs by system resulted in a matrix like that shown in table 5. The table shows that a number of systems could be considered common across aircraft. For example, all aircraft appear to have tasks dealing with flight controls and powerplants. Other categories, such as the power train, had either systems or subsystems that would be considered comparable across aircraft.

Table 5. Boundaries of the MOS 6112, 6113, 6114, and 6115 job performance domain [2]

		Main rotor				Tail rotor system							
Helicopter	Flight control system	Main rotor system	Rotor system	Power train system	Power plant system	Tail rotor system	Rotary rudder system	Oil cooler system	Fuel system	Utility system	Auxiliary power plant system	Auxiliary fuel system	External cargo hook system
(1) CH-46	X		X	Sub	X			Sub	X	X	X	Sub	Sub
(2) CH-53/A/D	X	X		Sub	X		X	Sub	X	X	X	Sub	X
(3) CH-53E	X	X		Sub	X		X	Sub	X	X	X	Sub	X
(4) UH-1N	X	X		X	X	X		X	X	X		Sub	Sub
(5) AH-1J	X	X		X	X	X		X	X				
(6) AH-1W	X	X		X	X	X		X	X			X	
(7) AH-1T	X	X		X	X	X		X	X			X	

Key: X = System identified in MATMEP.
Sub = System is a subtask of a larger system or is not included in the MATMEP.

The second activity was to determine which functions mechanics perform. The duty areas in the MATMEPs identified 12 common mechanic functions across the various aircraft systems, as shown in table 6. This table shows that the two activities most associated with troubleshooting—function check and fault isolation—are performed on all helicopter systems. Remove/replace is another function performed on all helicopter systems, while rig and adjust are performed on most helicopter systems. All other functions (e.g., scope, set, vibration analysis) apply to a small subset of helicopter systems.

Next, entries within the matrices needed to be rated so that their relative representativeness could be judged. Subject matter experts were asked to rate the aircraft systems according to the amount of knowledge, skills, and abilities required to perform them. The experts decided that troubleshooting and remove/replace functions demanded the most knowledge, skills, and abilities. This decision, which was confirmed by a second expert panel, thus identified eight "super cells" of the most representative systems and mechanical functions.

Since rig and adjust were considered the third and fourth most general mechanical functions, cells represented by those functions were considered "secondary super cells." Table 7 shows the results from the various panel meetings. This matrix formed the basis for selecting tasks from the job performance domain across the four MOSs.

Sampling Test Content

To begin selecting test content, a list of tasks was developed for each of the super cells and the additional secondary super cells shown in table 7. Then the helicopter technical manuals were analyzed to identify the behavioral elements for each task. These behavioral elements were described at a slightly higher level of generality than the step level. An example of one of the behavioral-element-by-task matrices is given in appendix B.

Tasks were then randomly selected from the super cells and secondary super cells to maximize coverage of the behavioral elements within each targeted cell. This procedure produced a list of initial tasks to be considered for testing. From this list, comparable tasks across MOSs were identified, as shown in table 8.

Table 6. A function-by-system matrix for helicopter mechanics [2]

		Rotor systems				Tail rotor system							
Helicopters:	1-7	2-7	1	1-7	1-7	4-7	2, 3	1-7	1-7	1-4	1, 2, 3	1-7	1, 2, 3, 4
	Flight control system	Main rotor system	Rotor system	Power train system	Power plant system	Tail rotor system	Rotary rudder system	Oil cooler system	Fuel system	Utility system	Auxiliary power plant system	Auxiliary fuel system	External cargo hook system
1. Function check	X	X	X	X	X	X	X	X	X	X	X	X	X
2. Fault isolation	X	X	X	X	X	X	X	X	X	X	X	X	X
3. Remove/replace	X	X	X	X	X	X	X	X	X	X	X	X	X
4. Rig	X	X	X		X		X				X		X
5. Adjust	X	X	X	X	X		X			X (4)	X		
6. Scope		X											
7. Set		X											
8. Tracks/balances		X	X			X	X						
9. Static balances						X							
10. Shims	X	X (2-5)	X	X (2-7)									
11. Repacks				X									
12. Vibration analysis		X	X	X	X (4-7)	X	X			X (6)			

Helicopters:
1 = CH-46
2 = CH-53A/D
3 = CH-53E
4 = UH-1N
5 = AH-1J
6 = AH-1W
7 = AH-1T

Table 7. MOS 6112, 6113, 6114, and 6115 job performance and testing domain [2]

		Main rotor				Tail rotor system							
Helicopters:	1-7	2-7	1	1-7	1-7	4-7	2, 3	1-7	1-7	1-4	1, 2, 3	1-7	1, 2, 3, 4
	Flight control system	Main rotor system	Rotor system	Power train system	Power plant system	Tail rotor system	Rotary rudder system	Oil cooler system	Fuel system	Utility system	Auxiliary power plant system	Auxiliary fuel system	External cargo hook system
1. Troubleshoot	X	X	X	X	X	X	X	X	X	X	X	X	X
2. Remove/replace	X	X	X	X	X	X	X	X	X	X	X	X	X
3. Rig	X	X	X	X	X		X				X		X
4. Adjust	X	X	X	X	X		X			X (4)	X		
5. Scope		X											
6. Set		X											
7. Tracks/balances		X	X			X	X						
8. Static balances						X							
9. Shims	X	X (2-5)	X	X (2-7)									
10. Repacks				X									
11. Vibration analysis		X	X	X	X (4-7)	X	X			X (6)			

Helicopters:
1 = CH-46
2 = CH-53A/D
3 = CH-53E
4 = UH-1N
5 = AH-1J
6 = AH-1W
7 = AH-1T

= Super cell
= Secondary super cell
Testing domain

Table 8. Comparable tasks tested across MOS [2]

6112 CH-46	6113 CH-53A/D	6114 UH-1N/AH-1W	6115 CH-53
TS flight controls	TS flight controls	TS flight controls	TS flight controls
R/R unitary pedal R/R collective pitch bellcrank Auxiliary power plant	R/R mechanical screwjack R/R collective pitch bellcrank Auxiliary power plant	R/R unitary pedal R/R collective pitch bellcrank * * *	R/R mechanical screwjack R/R collective pitch bellcrank Auxiliary power plant
TS main rotor	TS main rotor	TS main rotor	TS main rotor
R/R rotor head	R/R rotor head	R/R rotor head	R/R rotor head
R/R rotating scissors	R/R rotating scissors	R/R drive link	R/R rotating scissors
TS PP fuel system TS PP oil system TS PP control system	* * * TS PP oil system * * *	TS PP fuel system TS PP oil system TS PP control system	TS fuel system TS oil system * * *
R/R fuel boost pump	R/R fuel boost pump	R/R fuel boost pump	R/R fuel boost pump
TS MGB oil system TS MGB chiplights TS MGB drive shaft	* * * TS MGB chiplights TS MGB drive shaft	* * * TS MGB chip detector * * *	* * * TS MGB chiplights * * *
R/R PT drive shaft R/R sump oil filter	R/R PT drive shaft R/R sump oil filter	R/R PT drive shaft R/R sump oil filter	R/R PT drive shaft R/R sump oil filter
Adjust pitch control rod Adjust flight control rod	Adjust pitch control rod Adjust flight control rod	* * * Adjust flight control rod	Adjust pitch control rod Adjust flight control rod
Ground handling	Ground handling	Ground handling	Ground handling

Creating Testable Units

The selected tasks were then examined and described, for purposes of developing testable units. Testable units included instructions for the test administrator, procedures for task setup, a list of materials needed, and procedures for scoring and administering the test. The scoring procedure listed the steps examinees were required to perform and a set of criteria for judging examinee performance.

Preliminary Trial Testing

The previous activities defined a set of tasks and testing procedures, but these tests had not been administered to actual examinees. Therefore, preliminary trial tests—the same as those used for the automotive phase, described earlier—were conducted to serve as a "shakedown."

Final Test Tryouts

Once the procedures and scoring protocols were in a nearly final form, test administrators were trained in the scoring procedures. At the end of the training, week-long final test tryouts were conducted to prepare the administrators for the actual testing. Like the automotive phase of JPM testing, the final test tryouts and command review for the helicopter mechanics' testing were a final opportunity to review the clarity of instructions, the assignment of tests to stations, and the timing of individual tests.

Content Not Tested

The final test tryouts provided a last opportunity to drop tasks that could not be fitted into the allotted testing time. Once the last deletions were made, the coverage of the remaining tasks was assessed. Overall, few behavioral elements were not tested in at least one task. Appendix C lists the behavioral elements covered, by MOS.

SCORING AND QUALITY CHECKS FOR MECHANICAL HANDS-ON TESTS

So far, this memorandum has described the process of developing the tests for mechanical maintenance specialties. Given all the attention to careful test development, it was necessary to give equally careful attention to scoring and quality checks for the hands-on tests.

Scoring of the Hands-on Tests

Step Scores

Scoring the automotive and helicopter hands-on mechanical tests involved several special considerations. The first was that an experienced mechanic could skip steps specified in the technical manual based on a deeper understanding of the procedures involved and his past experiences. For example, whereas the manual might specify loosening several screws in order to take out several individual parts, the experienced mechanic may know that loosening one main screw would disconnect the entire component and save time. The experienced mechanic might also add steps that are not specified in the technical manual. For example, the mechanic might loosen a bolt in an earlier portion of the task, in anticipation of a later step where loosening that bolt would have been more difficult. In cases such as these, a strict "go/no-go" scoring would place the experienced mechanic at a disadvantage—the mechanic would be penalized for having improved upon procedures prescribed in the technical manual.

A second challenge was how to score troubleshooting tasks. The technical manual specifies a series of general steps that will pinpoint any problem, including those that occur infrequently. However, an experienced mechanic knows that certain problems are more likely to occur than others. Rather than follow general procedures, an experienced mechanic might immediately search for the most common problem, ignoring or skipping the general procedures specified in the technical manual. If the troubleshooting task were scored strictly "go/no-go" according to whether technical manual steps were performed, the experienced mechanic might be penalized even though that mechanic correctly diagnosed the problem in less time than it would take the less experienced mechanic.

These considerations led to a departure from the traditional "go/no-go" format for scoring each step. Instead, steps were scored as follows:

- "Go," if the step was performed correctly
- "No-go," if the step was performed incorrectly
- "Did not do," if the step was simply skipped or ignored

- "Could not do," if the step could not be attempted for reasons unrelated to the examinee's proficiency (e.g., equipment essential to step completion was broken or missing).

In addition, each task was timed to determine how quickly it was accomplished.[1] Furthermore, a score was added to the scoring sheet to indicate whether the task had been completed correctly. These "product" scores could be used to give credit to the person who skipped many steps but who nevertheless completed the assignment correctly. A final innovation was the inclusion of "not in the manual" steps, which were beneficial to perform but not required by the technical manual. For example, in the "adjust/align power steering assist cylinder" task, the manual fails to mention that loosening a clamp screw will make it easier to set the distance between two studs. Examinees who remembered to loosen the clamp screw were rated "go" on the not-in-the manual step "loosened clamp screw."

Task-Level Scores

The computation of task-level scores was altered to take advantage of the additional flexibility allowed by the nontraditional step scoring. To compute task-level scores, product steps and process steps had to be distinguished. In addition, it was necessary to reconfirm on which steps "did not do" should be counted as wrong, and on steps "did not do" should be considered neutral, because not doing the steps did not adversely affect performance. Based on feedback from subject matter experts, it was decided that for most steps, "did not do" should be scored as wrong. But for some steps, particularly in troubleshooting tasks, failure to perform should be considered neutral.

Such a scoring system allowed greater flexibility in interpreting step scores for later analysis. For example, the following types of performance indicators could be computed using this scoring system:

- Percentage correct on *essential* steps (i.e., in which failure to perform the step is counted as wrong)

- Percentage correct on *all* steps

- Percentage of tasks with correct "product"

1. Marines were aware that they were being timed, but they were given no instructions or incentive to work quickly.

- Percentage of "extra" (not-in-manual) steps correctly performed

- "Efficiency" defined as the percentage correct on essential steps divided by time to complete the task.

Quality Checks

The hands-on performance tests were administered to about 1,000 automotive mechanics; about 200 helicopter mechanics were tested for each of the respective aircraft. Separate ground and air teams of test administrators conducted the testing at the east and west coast test sites. The hands-on performance data were entered into computers at each test site to identify immediately any missing data and to allow for monitoring of test administrator scoring trends. Once all on-site data checks and quality analyses had been conducted, the data were transmitted to CNA for merging into the master JPM database and further processing. CNA conducted additional quality control tests and imputed missing data for individual cases as was warranted. These data quality analyses are documented elsewhere [3, 4].

Initial analyses of the hands-on data focused on the quality of measurement by each hands-on task by examining step-level performance data. The step analyses (analogous to item analyses for paper-and-pencil tests) examined step-total score correlations and step-task score correlations to identify steps that were potentially ambiguous or provided poor measurement. Low values on either of these correlation measures indicated that the step was not consistently measuring the same concept as the overall task or total hands-on scores. For the automotive mechanic hands-on test, 8 steps were deleted (out of 441 steps on the total test), and for the helicopter hands-on tests, 10 to 22 steps were deleted (out of 253 to 372 steps on the total test). Task scores were then computed based on all appropriate steps, and the scores were averaged to produce total scores for each MOS.

Site Comparisons

A second concern was to determine the consistency of hands-on measurement across testing sites. All MOSs were tested on both the east and west coasts except for the CH-53 A/D mechanics (6113), who were tested only on the west coast. The relationship between tasks, total hands-on score, time in service (TIS), and aptitude were examined separately by site for each MOS. The correlations among these variables were found to be very consistent for the two sites for all MOSs. However, large differences in the percent-correct scores for the total test were noted between the two sites for all helicopter MOSs (except MOS 6113, which was tested at only one site) (see tables 9 through 11). Similar site differences did not occur for the automotive mechanics.

Table 9. Hands-on task performance scores and site adjustments for CH-46 mechanics (MOS 6112)

Task	Site A Mean	Site A STD	Site B Mean	Site B STD	Site adjustment
1A	88.89	10.06	82.14	15.18	–7.77
1B	69.80	17.17	79.06	27.10	9.54
2A	95.54	11.37	78.62	22.66	–17.66
2B	90.45	13.52	60.96	22.07	–30.61
2C	93.78	9.95	78.73	13.92	–16.02
2D	79.42	16.69	77.03	16.57	–2.72
3A	91.03	12.00	69.86	19.89	–22.99
3B	97.11	4.58	87.81	16.49	–9.89
3C	96.63	7.50	85.06	14.09	–12.52
4A	95.06	6.74	84.99	11.63	–10.42
4B	74.95	23.23	56.73	24.73	–18.34
5A	93.07	7.45	90.57	8.82	–2.85
5B	82.01	15.08	81.89	13.10	–0.65
6A	86.52	18.29	87.61	20.05	–1.05
7A	91.13	13.40	78.04	17.10	–13.56
7B	85.89	22.38	83.04	18.97	–4.59
8A	91.06	12.32	87.49	12.84	–4.52
8B	87.72	12.78	96.61	9.90	9.04
8C	84.13	10.52	86.94	12.91	2.52
Forms	60.78	24.65	71.15	21.06	8.61
Manuals	83.09	16.37	84.14	12.05	–0.31
Total	86.52	6.61	80.38	8.00	
MM	113.13	7.70	116.54	10.20	
TIS	50.79	37.05	53.01	40.01	
N	95		79		

NOTE: Site adjustments retain performance differences due to aptitude and time in service; adjustments are added to site A hands-on scores.

Table 10. Hands-on task performance scores and site adjustments for U/AH-1 mechanics (MOS 6114)

Task	Site A Mean	Site A STD	Site B Mean	Site B STD	Site adjustment
1A	91.41	8.67	88.12	13.61	–1.81
1B	72.92	15.55	63.05	12.06	–9.40
2A	94.92	11.50	93.71	14.16	–0.67
3A	97.29	5.42	51.11	28.86	–44.94
3B	97.94	6.52	78.62	20.49	–17.89
4A	87.43	11.85	71.61	22.17	14.69
5A	89.16	8.28	74.46	21.12	–13.13
5B	78.10	21.87	36.90	23.49	–39.22
6A	90.48	9.28	85.27	9.55	–5.33
6B	84.52	21.26	79.11	20.64	–5.27
7A	74.78	20.28	62.43	18.95	–9.70
7B	93.71	8.32	87.32	12.94	–5.53
8A	86.67	19.44	72.56	20.59	–13.16
8B	85.65	14.56	70.73	21.84	–12.04
8C	76.48	27.34	67.13	25.66	–8.17
Forms	59.38	20.40	63.49	20.55	6.57
Manuals	83.17	17.78	85.91	15.80	5.06
Total	84.92	6.69	72.48	8.01	
MM	117.34	9.08	115.77	8.51	
TIS	59.25	42.00	39.69	24.25	
N	63		151		

NOTE: Site adjustments retain performance differences due to aptitude and time in service; adjustments are added to site A hands-on scores.

Table 11. Hands-on task performance scores and site adjustments for CH-53 E mechanics (MOS 6115)

Task	Site A Mean	Site A STD	Site B Mean	Site B STD	Site adjustment
1A	92.10	10.30	73.88	17.30	–18.58
1B	79.03	19.25	59.87	29.44	–20.61
1C	97.33	8.61	87.64	17.19	–9.96
1D	76.70	16.22	77.26	15.15	0.85
2A	98.33	3.76	89.10	12.40	–7.94
3A	98.60	3.88	86.54	17.58	–12.04
3B	94.90	6.91	81.76	15.71	–13.54
4A	95.07	8.39	79.58	15.30	–15.19
4B	92.18	13.60	78.25	24.26	–13.59
5A	96.97	5.92	89.52	13.04	–6.87
6A	91.70	11.98	56.91	26.89	–33.28
6B	96.00	6.43	74.27	18.76	–21.29
7A	97.65	5.50	90.29	10.03	–6.93
7B	95.77	7.72	71.80	15.85	–22.50
7C	83.58	18.23	61.64	21.72	–20.40
8A	97.87	3.86	91.74	10.16	–5.69
Forms	60.37	22.27	61.89	16.10	2.90
Manuals	90.02	14.87	84.98	16.61	–5.43
Total	90.82	4.64	77.62	8.48	
MM	116.02	10.39	114.69	11.29	
TIS	60.10	32.72	71.55	50.91	
N		60		89	

NOTE: Site adjustments retain performance differences due to aptitude and time in service; adjustments are added to site A hands-on scores.

Marine Corps manpower experts examined the hands-on scores and site differences to determine if such disparities reflected true performance differences or were merely artifacts of the hands-on testing process. It was noted that for two tasks that did not require test administrators for scoring (forms completion and use of technical manuals), such site differences were not found, or if a difference did occur, it was typically opposite the trend noted for the hands-on tasks. Job knowledge test scores were very similar for the two sites, and the sites did not vary in terms of the mechanical maintenance (MM) aptitude composite. Variations in time in service were not consistent with site differences in hands-on scores. Inspection of the step scores revealed that particular steps were scored much more leniently at site A than at site B. For these reasons, and based on prior Marine Corps experiences and their knowledge of the hands-on tests, the manpower experts concluded that score differences overestimated any true performance differences between the two test sites.

Regression analyses were conducted for each task within each MOS to estimate the degree to which task performance differences were due to aptitude and time-in-service differences between the two sites. Variance in performance scores due to such explainable differences should be retained if task scores are adjusted to correct for site effects. The last column of tables 9 through 11 provides the computed adjustments for each task. The adjustments are applied to the task scores of one site, consistent with what the manpower experts believed to reflect the overall level of performance in the fleet for these MOSs.

The site adjustments preserved the relationships among primary variables of interest: time-in-service, aptitude, and hands-on score. For some tasks, the influence of TIS and aptitude on task performance was minimal, so the adjustments essentially reflect the differences in mean task performance. Given the consistency of differences in task performance by site and across MOS and the consensus among job experts that the differences in actual proficiency across sites were minimal, such adjustments are warranted. The site-adjusted performance scores can now be aggregated without artificially distorting correlations for the pooled data.

CONCLUSIONS

The procedures that were followed for the development and scoring of the mechanical maintenance hands-on performance tests were designed to ensure that valid inferences could be drawn from hands-on test scores to Marines' job performance. ITSs were used as a foundation for defining job requirements. Marine Corps subject matter experts then rated each job requirement for its representativeness to the job as a whole. Selection among those tasks that were judged to be the most representative was accomplished by a sampling procedure that maximized the number of different behavioral elements to be tested.

After tasks were selected, tryout testing allowed preliminary assessments of tasks' feasibility, time limits, and procedures. Retired and former Marine mechanics, hired to serve as test administrators, were given two weeks of training to ensure that properly reliable and valid scoring would be maintained. During test administration, continual monitoring ensured that high levels of inter-rater agreement were maintained, and that scoring criteria did not drift over time. Hands-on performance data were entered into computers at each test site to identify immediately any missing data and to allow for monitoring of test administrator scoring trends.

Hands-on performance steps were scored in a manner that ensured that experienced mechanics would not be penalized for using procedures that were more efficient than those specified by the technical manuals. After testing was completed, data were transmitted to CNA for additional quality control tests; missing data were imputed where warranted. Initial analyses examined step-total and step-task score correlations to identify and delete steps that were ambiguous or provided poor measurement.

The consistency of hands-on measurement across testing sites was also examined. The relationship between tasks, total hands-on score, time in service, and aptitude were found to be very consistent for the two sites across all MOSs. However, there were large differences in the percentage of correct scores for the total test between the two test sites for all helicopter MOSs (except 6113, which was tested at only one site). Marine Corps manpower experts examined hands-on scores and site differences to determine if such disparities reflected true performance differences or were merely artifacts of the hands-on testing process. The sites did not differ on job knowledge, or on the two tasks that did not require test administrators for scoring; nor did the sites vary in terms of mechanical maintenance (MM) composite. Manpower experts concluded that score differences overestimated any true differences in performance across the two sites. Therefore, on the recommendation of the Marine Corps manpower experts, adjustments were made to compensate for apparent discrepancies in the scoring procedures made in the two testing sites. These adjustments prevented artificial distortions for the pooled data.

The goals of these procedures were to ensure that the most representative tasks were sampled and tested in an objective manner. As a result of these development and scoring procedures, the scores that come from the mechanical maintenance phase of the Job Performance Measurement (JPM) Project are highly reflective of performance in the actual job domain.

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APPENDIX A

BEHAVIORIAL ELEMENT MATRICES FOR MARKER CELLS OF THE AUTOMOTIVE MECHANICS JOB REQUIREMENTS DOMAIN

Table A-1. Behavioral element matrix for "Inspect" marker cells of the automotive mechanic job requirements domain

	Not tested		Tested						
Function:	Inspect brakes	Inspect drive train	Troubleshoot electrical system		Troubleshoot engine		Troubleshoot hydraulic system		
Task (Vehicle):	No tasks	No tasks	Stoplights inoperative (813)	Test battery voltage with STE/ICE (923)	Engine starts but fails to keep running (923)	Excessive oil consumption (998)	Winch will not operate (LVS)	Inoperative hydraulic low-oil-level alarm light (LVS)	Inoperative folding boom (LVS)
Behavioral elements									
Follow specific safety instructions	•			X	X		X	X	X
Look for wear (loss of material, deterioration)	•	•	X						
Look for damaged/defective parts (cracks, kinks, breaks, bends)	•	•	X		X	X	X	X	
→ Look for discoloration (material is intact but off-color)									
Look for contamination (material is intact)	•	•	X						
Check for proper installation (mounting, fasteners tight)	•	•	X		X	X			
Look for missing parts	•	•	X		X				
Look for fluid leaks	•	•			X	X	X		
→ Listen for air leaks									
Locate information in manual	•	•	X	X	X	X	X	X	X
Read manual	•	•	X	X	X	X	X	X	X
Follow general safety precautions	•	•	X	X	X	X	X	X	X
Fill out forms	•	•		X					

NOTE: X means behavioral element was tested.
→ means behavioral element was not tested.
• means behavioral element was tested in context of another task.

Table A-2. Behavioral element matrix for "Service" marker cells of the automotive mechanic job requirements domain

Function:	Service brakes		Service engine	
Task (Vehicle):	Master cylinder* (813)	Bleed system pressure method* (813)	Service radiator (LVS)	Service oil system (923)
Behavioral elements				
Follow explicit safety instructions	X	X	X	
Pour fluid into reservoir	X	X		
Loosen nut/bolt with wrench	X	X		
Pry mechanism to loosen/tighten	X	X		
Remove piece by pulling loose	X	X		
Install piece by pushing	X	X		
Open/close rotary valve by hand		X		
Tighten nut/bolt with wrench		X		
Wipe surfaces clean of dirt	X	X		
→ Lubricate surface				
Open/close valve with wrench		X		
Prepare bleeder ball for use		X		
Give instructions to assistant		X		
Follow general safety precautions	X	X		
Select proper tools	X	X		
Fill out forms	X	X	X	X
Locate information in manual	X	X	X	X
Read manual	X	X	X	X
→ Allow to air dry				
→ Wash/rinse in warm (non-sudsy) water				

(Continued on next page)

Table A-2. (*Continued*)

Function:	Service brakes		Service engine	
Task (Vehicle):	Master cylinder* (813)	Bleed system pressure method* (813)	Service radiator (LVS)	Service oil system (923)
Remove dirt and rust with compressed air			X	
Loosen drain plug/gasket/cap			X	X
Drain fluid			X	X
Install gasket/drain/plug/cap			X	X
Torque bolt				X
Pour fluid into reservoir			X	X
Clean item with dry-cleaning solvent			X	X
Dry piece with compressed air			X	X
Test alkalinity of fluid			X	
Coat seal with oil				X
Screw on oil filter by hand			√	
Follow general safety precautions			X	X
Select proper tools			X	X

NOTE: X means behavioral element was tested.
→ means behavioral element was not tested.
* "Service Master Cylinder" and "Bleed Brake System" were combined for testing.
√ This was tested in LVS radiator task, because a coolant filter was screwed on.

Table A-3. Behavioral element matrix for "Troubleshoot" marker cells of the automotive mechanic job requirements domain

Function:	Troubleshoot electrical system		Troubleshoot engine		Troubleshoot hydraulic system		
Task (Vehicle):	Stoplight(s) are inoperative (813)	Test battery voltage with STE/ICE (923)	Excessive oil consumption (998)	Engine starts but fails to keep running (923)	Winch will not operate (LVS)	Inoperative hydraulic low-oil-level alarm light (LVS)	Inoperative folding boom (LVS)
Behavioral elements common to both standard and STE/ICE methods:							
Find correct starting point in manual	X	X	X	X	X	X	X
Follow steps correctly	X	X	X	X	X	X	X
Make correct decisions	X	X	X	X	X	X	X
Operate vehicle controls and observe results	X			X	X		X
Give correct instructions to assistant	X						
Look for missing parts	□		X				
Look/feel for damaged/defective parts	□			X	X		
Look/feel for loose parts/improper connections	□		X	X			
Look/feel for corrosion	□						
Look/feel for fluid leaks			X	X	X		
Look/feel for wear*							
Check for contamination				X			
→ Test specific gravity of electrolyte							
→ Check for overheating							
→ Charge batteries							
Standard method							
Test voltage w/meter—large parts*							
Test voltage w/meter—small parts (limited connects)	X				X		

(Continued on next page)

Table A-3. (*Continued*)

Function:	Troubleshoot electrical system		Troubleshoot engine		Troubleshoot hydraulic system		
Task (Vehicle):	Stoplight(s) are inoperative (813)	Test battery voltage with STE/ICE (923)	Excessive oil consumption (998)	Engine starts but fails to keep running (923)	Winch will not operate (LVS)	Inoperative hydraulic low-oil-level alarm light (LVS)	Inoperative folding boom (LVS)
Test voltage with meter-small parts (multiple connects)	X						
Test continuity with meter-small parts (limited connects)					X	X	
→ Test continuity with meter-small parts (multiple connects)							
→ Test resistance with meter							
Test for voltage with a test lamp	□						
Test circuits by opening and closing them	□						
STE/ICE method							
Set up and calibrate STE/ICE		X					
Run STE/ICE test		X					
→ Look for corrosion							
Follow explicit safety instructions					X	X	X
Check lines/assembly for blockage				X	X		X
Test fluid levels					X	X	X
Check indicator for color reading				X			
Check valve position				X			
→ Check for air in system							
→ Pressurize cooling system							
Follow general safety precautions			X	X	X	X	X

(*Continued on next page*)

Table A-3. (*Continued*)

Function:	Troubleshoot electrical system		Troubleshoot engine		Troubleshoot hydraulic system		
Task (Vehicle):	Stoplight(s) are inoperative (813)	Test battery voltage with STE/ICE (923)	Excessive oil consumption (998)	Engine starts but fails to keep running (923)	Winch will not operate (LVS)	Inoperative hydraulic low-oil-level alarm light (LVS)	Inoperative folding boom (LVS)
Connect/disconnect connector					X		
Check for overloading (excessive weight)							X
Check for binding parts							X
Install jumper wire					X		
Test pressure using gauge							X
Check for continuity					X	X	
Torque nut					X	X	
→ Remove insulation from wire							
Fill out forms*							

NOTE: X means behavioral element was tested.
→ means behavioral element was not tested.
* means behavioral element was tested as part of another task in a different function.
□ not in manual but known in field.

Table A-4. Behavioral element matrix for "Test" marker cells of the automotive mechanic job requirements domain

	Not tested		Tested						
Function:	Test electrical system	Test hydraulic system	Troubleshoot electrical system		Troubleshoot engine		Troubleshoot hydraulic system		
Task (Vehicle):	No tasks	No tasks	Stoplights inoperative (813)	Test battery voltage with STE/ICE (923)	Engine starts but fails to keep running (923)	Excessive oil con-sumption (998)	Winch will not operate (LVS)	Inoperative hydraulic low-oil-level alarm light (LVS)	Inoperative folding boom (LVS)
Behavioral elements									
Follow specific safety instructions	•	•		X			X	X	X
Set switch to proper position	•			X					
Interpret instrument reading	•			X			X	X	
Calibrate meter scale (if req. by meter)	•			X	X				
Connect probes across items	•			X					
Observe operation of electrical component	•			X					
Install meter probes on meter									
Install/remove jumper wires	•						X	X	
Operate vehicle controls & observe results	•			X		X	X	X	
Prepare test equipment	•			X					
Follow general safety precautions	•			X	X	X	X	X	X
Select proper tools	•			X					
Fill out forms	•			X					
Read manual	•		X	X					
Locate information in manual	•		X	X					
Place lever switch in proper position		•							□
Operate winch manually									
Operate winch remotely		•							X
Unplug electrical connector		•					X	X	

(Continued on next page)

Table A-4. (*Continued*)

	Not tested		Tested						
Function:	Test electrical system	Test hydraulic system	Troubleshoot electrical system		Troubleshoot engine		Troubleshoot hydraulic system		
Task (Vehicle):	No tasks	No tasks	Stoplights inoperative (813)	Test battery voltage with STE/ICE (923)	Engine starts but fails to keep running (923)	Excessive oil con-sumption (998)	Winch will not operate (LVS)	Inoperative hydraulic low-oil-level alarm light (LVS)	Inoperative folding boom (LVS)
Remove pressed-on component		•						□	
Set multimeter rotary switch to proper position		•					X	X	
Connect multimeter leads to proper contacts		•					X	X	
Read multimeter correctly		•	X				X	X	
→ Interpret dipstick fluid level reading									
Connect jumper wire		•					X	X	

NOTE: X means behavioral element was tested.
→ means behavioral element was not tested.
• means behavioral element was tested in context of another task.
□ not in manual but known in field.

Table A-5. Behavioral element matrix for "Adjust/Align" marker cells of the automotive mechanic job requirements domain

Function:	Adjust/align steering system		
Task (Vehicle):	Power-steering pump belt (1008)	Power-steering assist cylinder (travel adjustment) (813)	Toe in/out (998)
Behavioral elements			
Loosen bolt/screw (do not remove)	X	X	X
Loosen nut (do not remove)		X	X
→ Tighten belt with pry bar			
Tighten screw/bolt	X	X	
Tighten nut		X	X
Read belt tension with gauge	X		
Install adjusting clamp		X	
Rotate assembly clockwise		X	X
Rotate assembly counterclockwise		X	X
Position/remove gauge between wheels**			X
Move scale (gauge)/(string)/(chalk line)			X
Read scale/measurement/(string)/(chalk line)		X	X
Loosen clamp		X	X
Loosen wheel with puller tool			X
Realign steering wheel			X
Torque nut/bolt/screw		X	X
Remove and install cotter pin*			
Jack wheels up/down*			
Give instructions to assistant			X
Follow general safety precautions	X	X	X

(Continued on next page)

Table A-5. (*Continued*)

Function:	Adjust/align steering system		
Task (Vehicle):	Power-steering pump belt (1008)	Power-steering assist cylinder (travel adjustment) (813)	Toe in/out (998)
Select proper tools	X	X	X
Fill out forms	X	X	X
Locate information in manual	X	X	X
Read manual	X	X	X

NOTE: X means behavioral element was tested.
→ means behavioral element was not tested.
* means behaviorial element was tested as part of another task in a different function.

Table A-6. Behavioral element matrix for "Repair and Replace" marker cells of the automotive mechanic job requirements domain

Function:	Repair and replace brake system		Repair and replace drive train			
Task (Vehicle):	Brake shoes (1008)	Parking brake cable* (998)	Neutral start switch (923)	Rear propeller shafts* (998)	Universal joints (998)	Runflat assembly (998)
Behavioral elements						
Follow explicit safety instructions	X		X		X	X
Withdraw/pull forward on mechanism	X	X	X	X	X	X
Unhook/remove expansion spring	X					
Remove coil compression spring	X					
Depress tabs on nut	X					
Remove washer/bushing	X	X		X		
Loosen nut by hand	X	X	X	X		X
Loosen nut by wrench		X	X	X		X
Depress/push mechanism by hand	X	X		X	X	
Tighten nut by wrench		X	X	X		X
Tighten nut by hand	X	X	X	X		X
Install washer/bushing	X	X		X		X
Position tabs on nut	X					
Install coil compression spring	X	X				
Rehook/install expansion spring	X					
→ Disconnect fluid line using line wrench						
→ Connect fluid line using line wrench						
Pry mechanism to either loosen/tighten				X	X	X
Torque nut		X		X		
Loosen/tighten screw		X		X		X

(Continued on next page)

Table A-6. (*Continued*)

Function:	Repair and replace brake system		Repair and replace drive train			
Task (Vehicle):	Brake shoes (1008)	Parking brake cable* (998)	Neutral start switch (923)	Rear propeller shafts* (998)	Universal joints (998)	Runflat assembly (998)
→ Compress mechanism with C-clamp						
Follow general safety precautions	X	X	X	X	X	X
Select proper tools	X	X	X	X	X	X
Fill out forms	X	X	X	X	X	X
Locate information in manual	X	X	X	X	X	X
Read manual	X	X	X	X	X	X
R & R cotter pin		X				
Remove gaskets/seals/O rings				X	X	X
Install gaskets/seals/O rings				X	X	X
Clean parts				X	X	X
Operate vehicle controls			X	X		
Remove and install retaining clips				X	X	
Apply grease or sealant				X	X	
Connect/disconnect male/female connector			X			
Install grease packets						X

X means behavioral element was tested.
→ means behavioral element was not tested.
* means "Parking brake cable" and "Rear propeller shafts" were combined for testing.

APPENDIX B

SKILL-BY-BEHAVIORIAL-ELEMENT MATRIX
FOR HELICOPTER MECHANICS

APPENDIX B

SKILL-BY-BEHAVIORIAL-ELEMENT MATRIX FOR HELICOPTER MECHANICS

	Lube systems	Main gearbox	Accessory gearbox	Drive shaft system
Manipulate electrical switches	x	x	x	
Disconnect plugs/switches	x	x	x	
Disconnect wires		x	x	
Check advisory light (VI)	x	x	x	
Reconnect plugs/switches	x	x	x	
Connect wires	x	x	x	
Read gauges	x	x	x	
Check fluid levels (VI)	x	x	x	
Check for leads (VI)	x	x	x	
Check for dirt (filters) (VI)	x	x	x	
Remove accessories	x	x	x	x
Connect accessories	x	x	x	x
Check fluids for contamination	x	x	x	
Perform oil analysis	x	x	x	
Drain fluids	x	x	x	

SOURCE: American Institutes for Research Report AIR-70900-FR 02/91. *Develop and Administer Job Performance Measures for the Mechanical Maintenance Occupational Area,* Volume I: *Test Development,* J. L. Crafts et al., Feb 1991.

APPENDIX C

CONTENT TESTED FOR EACH MARKER CELL FOR HELICOPTER MECHANICS, BY MOS

APPENDIX C

CONTENT TESTED FOR EACH MARKER CELL FOR HELICOPTER MECHANICS, BY MOS

Marker cell tasks	MOS			
Behavioral element	**6112**	**6113**	**6114**	**6115**
Measure/record distance using ruler	•	•	•	•
Connect components	•	•	•	•
Connect accessories	•	•	•	•
Inspect for FOD and cleanliness	•	•	•	•
Apply electrical power	•	•	•	•
Remove electrical power	•	•	•	•
Record information on maintenance forms	•	•	•	•
Use precision measuring equipment	•	•	•	•
Use special tools	•	•	•	•
Clean with cloth	•	•	•	•
Safety wire	•	•	•	•
Turn on power using APP	•	•		•
Turn off power [turn off APP]	•	•		•
Disconnect accessories	•	•	•	•
Adjust component	•	•	•	•
Lift blade		•		•
Lower blade		•		•
Check for proper engagement	•	•	•	•
Remove gaskets/seals/O-rings	•	•	•	•
Disconnect hoses/tubes/lines	•	•	•	•
Loosen check nuts		•		•
Install gasket/seals/O-rings	•	•	•	•
Connect hoses/tubes/lines	•	•	•	•
Adjust accessories	•	•	•	•
Straighten tangs on key washer				
Bend tangs on key washer				
Check switches/valves/levers for proper position	•	•	•	•
Cap off lines	•	•	•	•
Remove/inspect chip detectors	•	•	•	•
Check for thread engagement				
Adjust rods/bearings	•	•	•	•
Use antifreeze compound				
Loosen nuts	•	•	•	•
Tighten lock-nut by hand		•		•

(*Continued on next page*)

Marker cell tasks	MOS			
Behavioral elements	**6112**	**6113**	**6114**	**6115**
Manipulate electrical switches	•	•	•	•
Disconnect plugs/switches	•	•	•	•
Manipulate flight controls	•		•	
Check advisory light	•	•		•
Reconnect plug	•	•	•	•
Read gauges	•		•	
Adjust friction			•	
Check that accessories/components are within tolerance	•	•	•	•
Use spring scale to check pull			•	
Check for play	•	•	•	•
Check for fluid leaks	•	•	•	•
Visually inspect components for integrity/damage	•	•	•	•
Check mechanical operation	•	•	•	•
Check for corrosion	•	•	•	•
Select maintenance tools	•	•	•	•
Manipulate maintenance tools	•	•	•	•
Check for binding				
Select correct component to troubleshoot	•	•	•	•
Use dial indicators	•	•	•	•
Use manuals	•	•	•	•
Shims	•	•	•	•
Rigs	•			
Torque	•	•	•	•
Disconnect control rods/bellcranks/supports	•	•	•	•
Remove cotter pins/nuts/washers/bushings/clamps/shims	•	•	•	•
Remove large bolts	•	•	•	•
Install large bolts	•	•	•	•
Remove component	•	•	•	•
Remove accessories	•	•	•	•
Align components for installation/removal	•	•	•	•
Install cotter pins/nuts/washers/bushings/clamps/shims	•	•	•	•
Align accessories for installation/removal	•	•	•	•
Connect control rods/bellcranks/supports	•	•	•	•
Apply primer (spray)				
Use gauge to check gaps or clearance	•	•	•	•

SOURCE: American Institutes for Research Report AIR-70900-FR 02/91. *Develop and Administer Job Performance Measures for the Mechanical Maintenance Occupational Area*, Volume I: *Test Development*, J. L. Crafts et al., Feb 1991.